



Johnson Space Center



NASA Tech Briefs Webinar

Improved Non-Destructive Methods for Composite Materials

Using Novel Flash IR Thermography

Techniques and Software

September 2014

Ronnie Clayton



HUMAN EXPLORATION

NASA's Path to Mars



EARTH RELIANT

MISSION: 6 TO 12 MONTHS
RETURN TO EARTH: HOURS



Mastering fundamentals
aboard the International
Space Station

U.S. companies
provide access to
low-Earth orbit

PROVING GROUND

MISSION: 1 TO 12 MONTHS
RETURN TO EARTH: DAYS



Expanding capabilities by
visiting an asteroid redirected
to a lunar distant retrograde orbit

The next step: traveling beyond low-Earth
orbit with the Space Launch System
rocket and Orion spacecraft



MARS READY

MISSION: 2 TO 3 YEARS
RETURN TO EARTH: MONTHS



Developing planetary independence
by exploring Mars, its moons and
other deep space destinations

Technology Transfer Program Resources

"Bringing NASA Technology Down to Earth"



QUICKLAUNCH

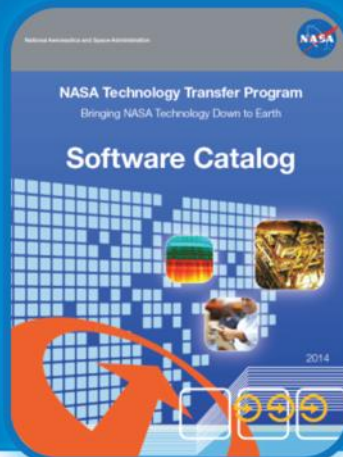
To quickly turn your license application into a license agreement and transfer the technology to you.



<https://quicklaunch.ndc.nasa.gov/>

SOFTWARE CATALOG

Organized into fifteen broad categories, the new catalog offers a wide variety of applications for use by industry, academia, other government agencies, and the general public.



http://technology.nasa.gov/NASA_Software_Catalog_2014.pdf

SPINOFF

Demonstrating the possibilities of applying NASA technology in different environments.



<http://spinoff.nasa.gov>

Johnson Space Center



Technology Transfer Success



REJUVEL® ANTI-AGING FACE CREAM



The key ingredient in REJUVEL® product formulas is a composition consisting of polypeptide growth factors and immunomodulating agents derived from 3-D cell cultures of human dermal fibroblasts grown using NASA patented technology* in a bioreactor in a microgravity environment.



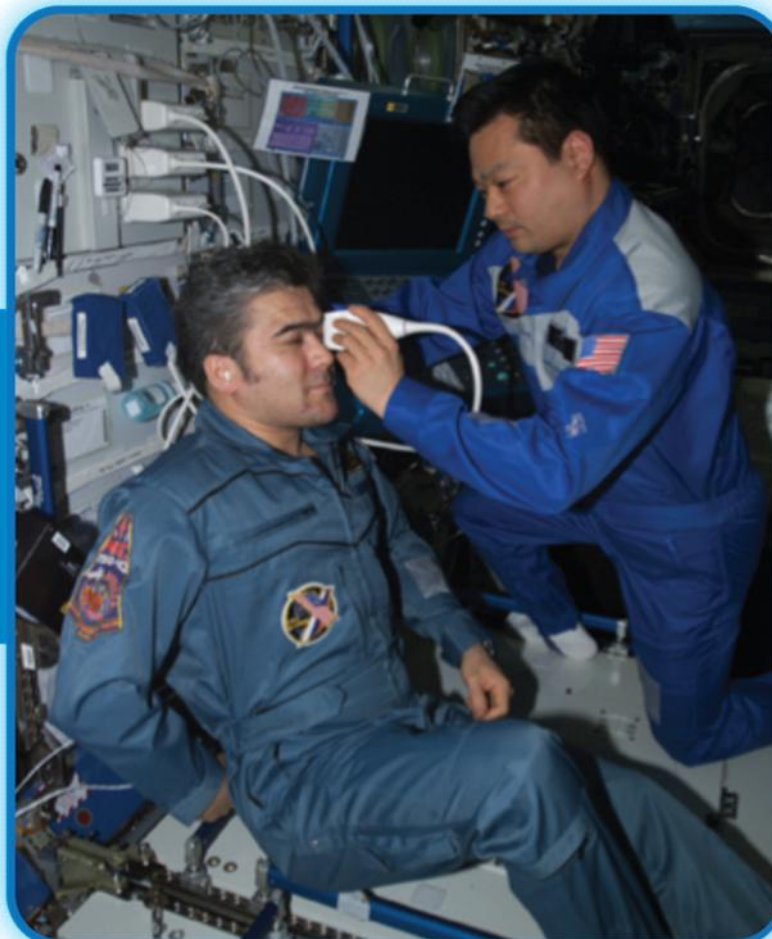
*Licensed from the National Aeronautics and Space Administration and Administrators of the Tulane Educational Fund under U.S. Patent No. 6,730,498,

The Future Is Here.

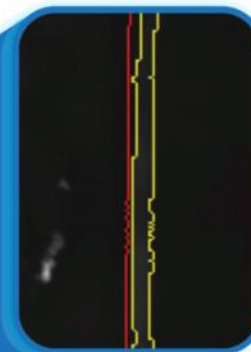
Technology Transfer Success



**ADVANCED DIAGNOSTIC
ULTRASOUND IN MICROGRAVITY
(ADUM)**



Today's Licensing Opportunity: Infrared Contrast Analysis and Imaging



INFRARED
THERMOGRAPHY
IMAGE

YELLOW LINES MARK
DAMAGE BOUNDARY

Benefits of IR Contrast Techniques



- Best available characterization of flaws and anomalies in nonmetallic composite structures
 - Detects smaller flaws
 - Quantitative and qualitative information about shape, size, depth, and location
 - Automatically defines flaw boundaries
- Faster and easier to use (saves time and money)
- More reliable (calibrated, objective, repeatable)
- Compatible with existing hardware systems (cost-effective)

Dr. Ajay Koshti



Novel Flash IR Thermography Techniques and Software Routines



**“Normalized Contrast”:
Processed Thermography Response**

**Goal: Improved
Flaw Characterization**

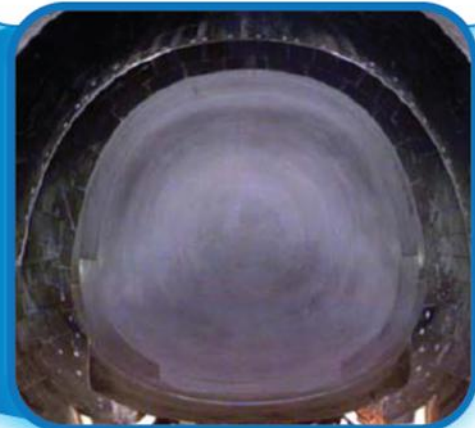
Intellectual Property

- US Patent 8,577,120
- Patent Pending

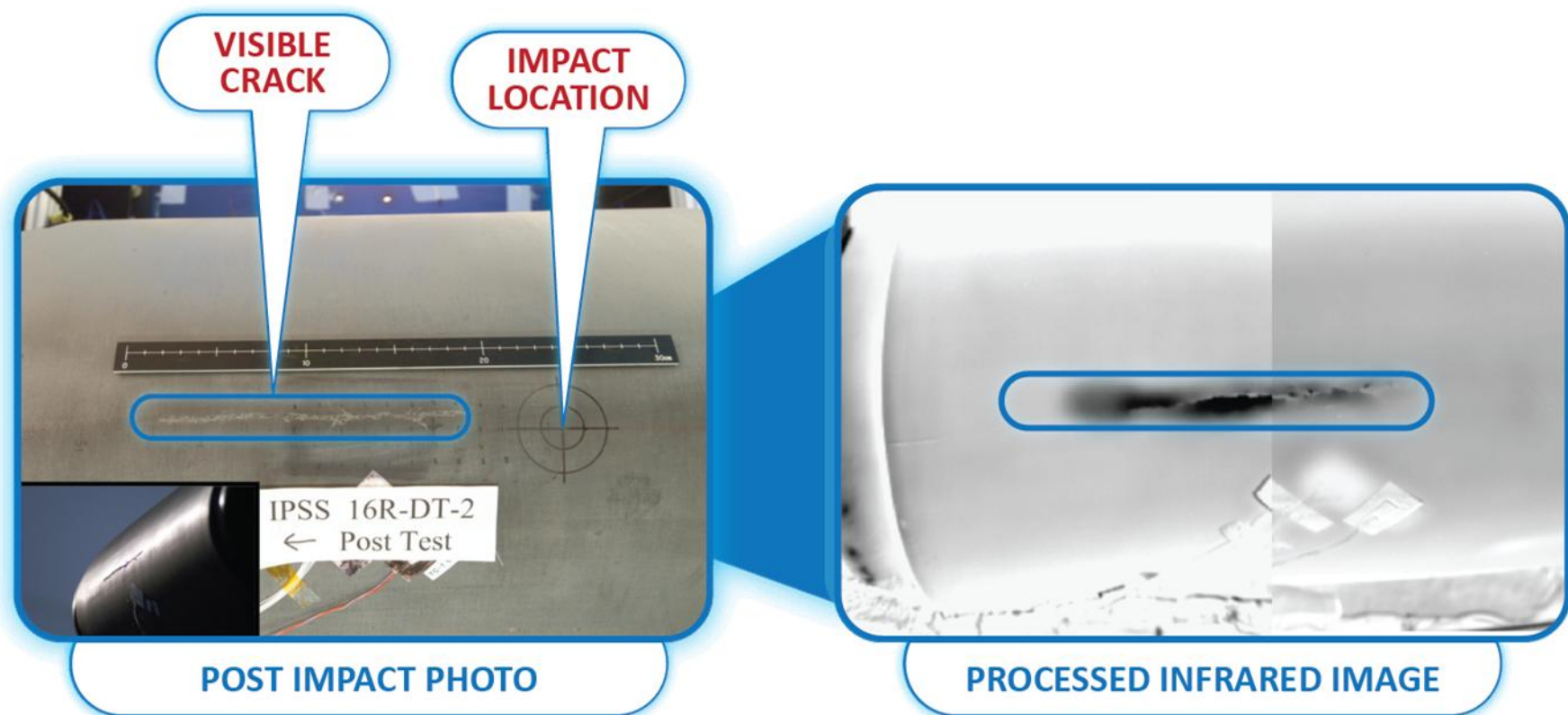
IR Contrast Originated in Space Shuttle Program



ORBITER NOSE CAP



RCC Damage Tolerance Impact Test on the Orbiter Wing Leading Panel





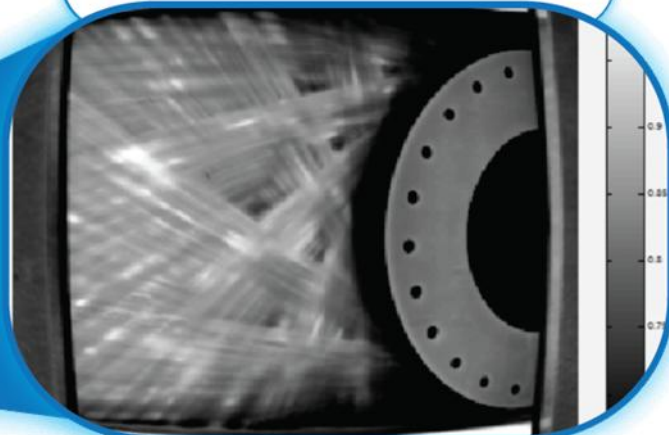
IR Contrast Analysis of Graphite/Epoxy Fiber Tank

ALL COMPOSITE FUEL TANK
MORPHEUS PROJECT



SHOT AREA

NORMALIZED CONTRAST IMAGE



LIGHT AREAS
INDICATE VOIDS

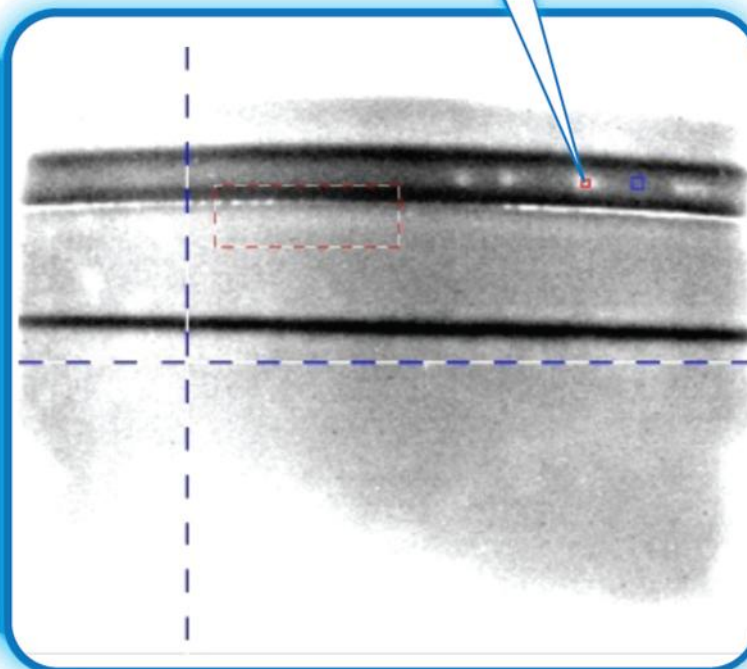
NDE of International Space Station (ISS) Radiator Panels



FLASH THERMOGRAPHY OF
ISS RADIATOR PANELS



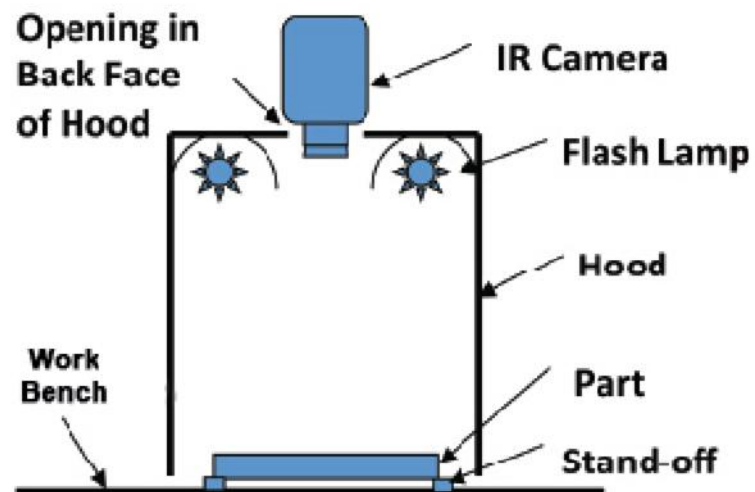
VOID INDICATION IN INFRARED
THERMOGRAPHY IMAGE





Flash IR Thermography Equipment and Setup

SCHEMATIC OF FLASH HOOD



INSPECTION OF SHUTTLE ORBITER WING USING FLASH INFRARED THERMOGRAPHY AT NASA KSC



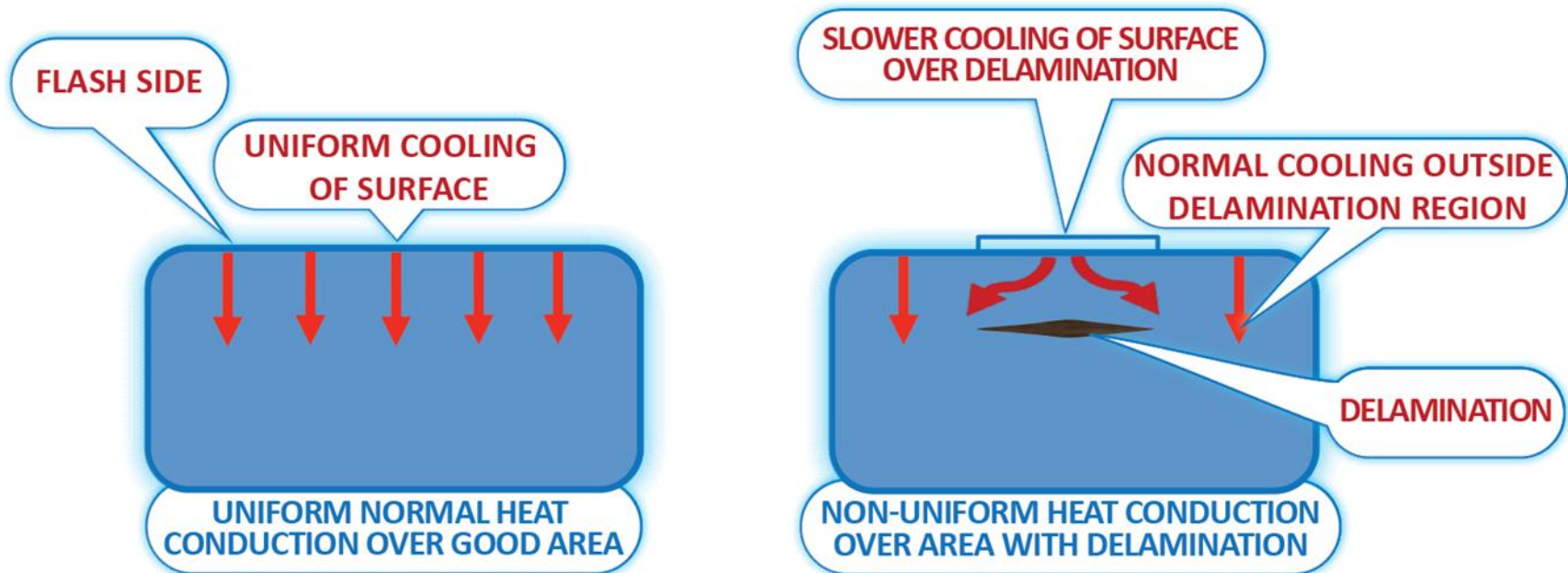
DATA ACQUISITION SYSTEM,
FLASH LAMP POWER SUPPLY
FLASH DURATION CONTROLLER

FLASH HOOD

Principle of Flash Thermography Delamination Detection

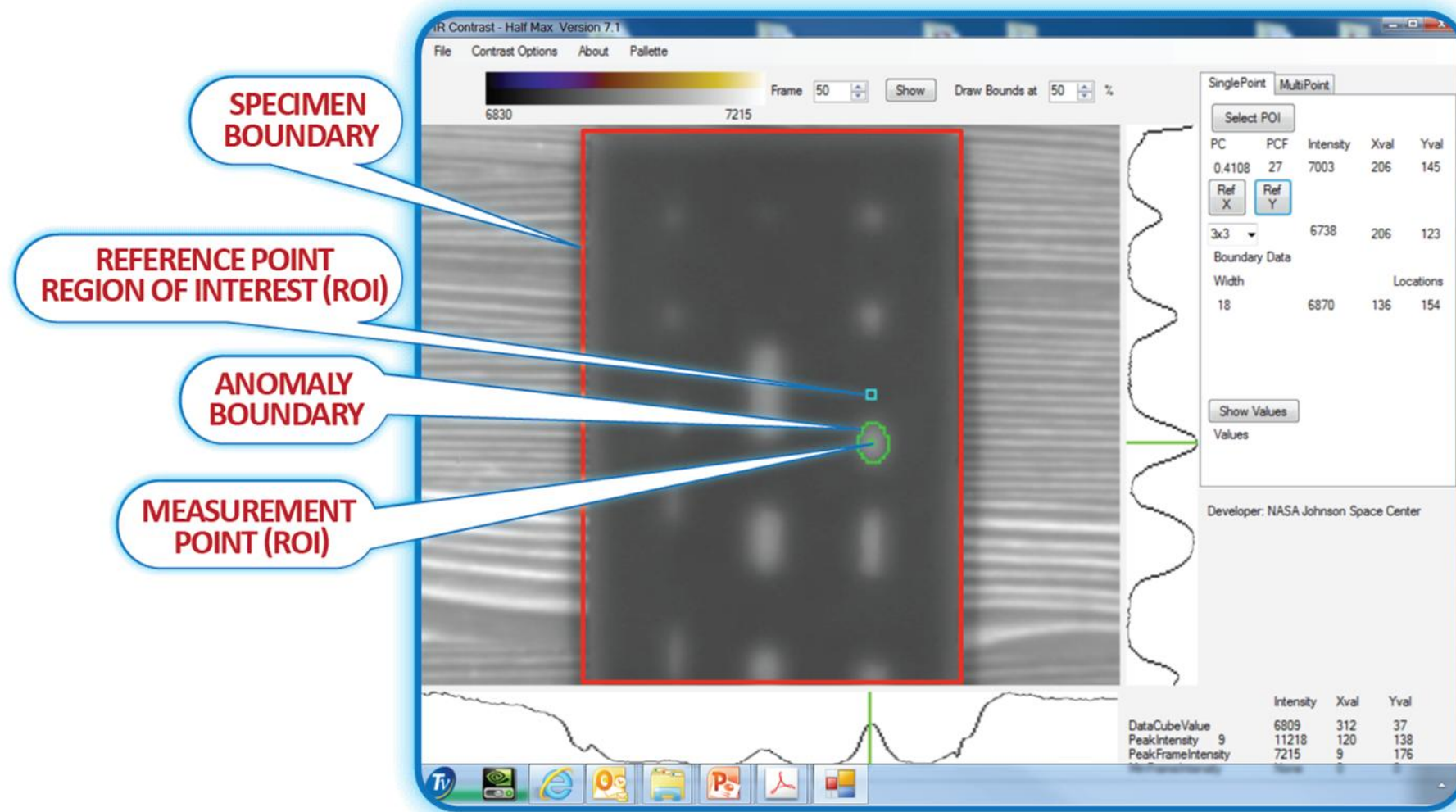


SCHEMATIC OF HEAT FLOW THROUGH CROSS SECTION OF THE PART



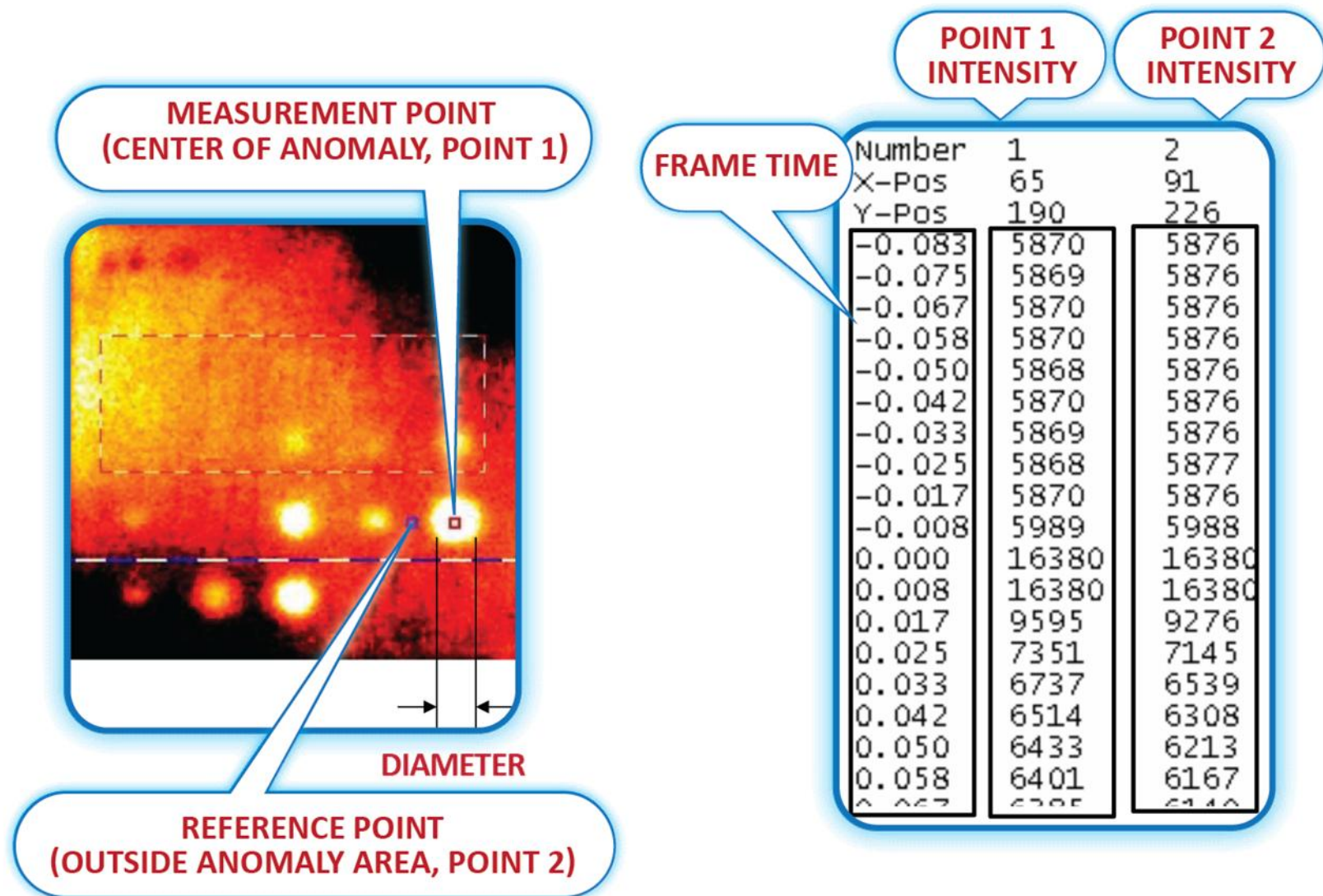
Slower surface cooling in the delamination region is detected by Infrared camera as warmer surface area.

Single Point Contrast Data Extraction and Boundary Identification

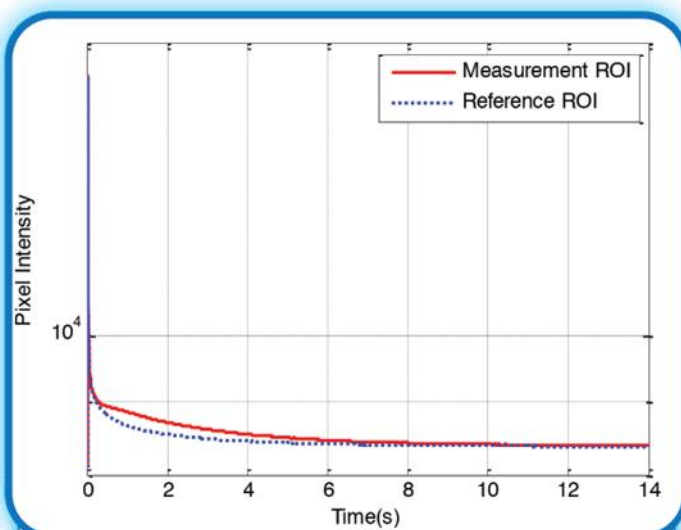


Normalized IR Contrast

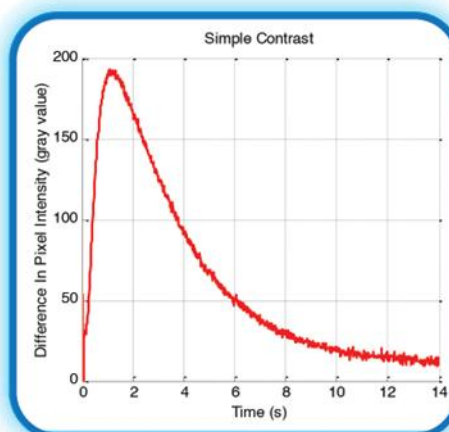
Single Point Data Extraction



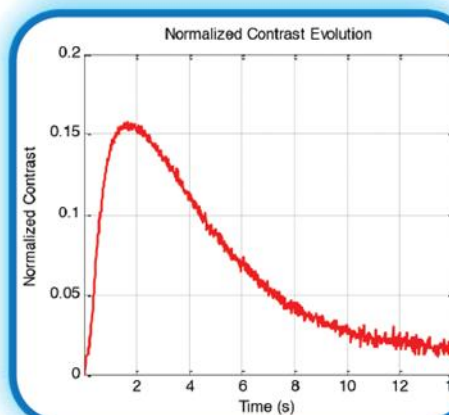
Primary Difference Between Commercial Software and IR Contrast Method



COMMERCIAL SOFTWARE: PROCESSING IS IN PIXEL INTENSITY DECAY DOMAIN, EXCELLENT FLAW DETECTION



CONCEPT OF SIMPLE CONTRAST EVOLUTION: SIMPLE CONTRAST IS CAMERA DEPENDENT



CONCEPT OF NORMALIZED IR CONTRAST EVOLUTION: NORMALIZED CONTRAST IS CAMERA INDEPENDENT

IR CONTRAST PROCESSING IS IN NORMALIZED CONTRAST EVOLUTION DOMAIN: MEANT FOR FLAW CHARACTERIZATION AND FOR DETECTION.



Definition of Normalized IR Contrast

T = Temperature or pixel intensity of Measurement point at time t

$T0$ = Average Temperature or pixel intensity of Measurement point just before Flash

TR = Temperature or pixel intensity of Reference point at time t

$TR0$ = Average Temperature or pixel intensity of Reference point just before Flash

\overline{C}^t = Normalized IR Contrast

$$\Delta T = T - T^0$$

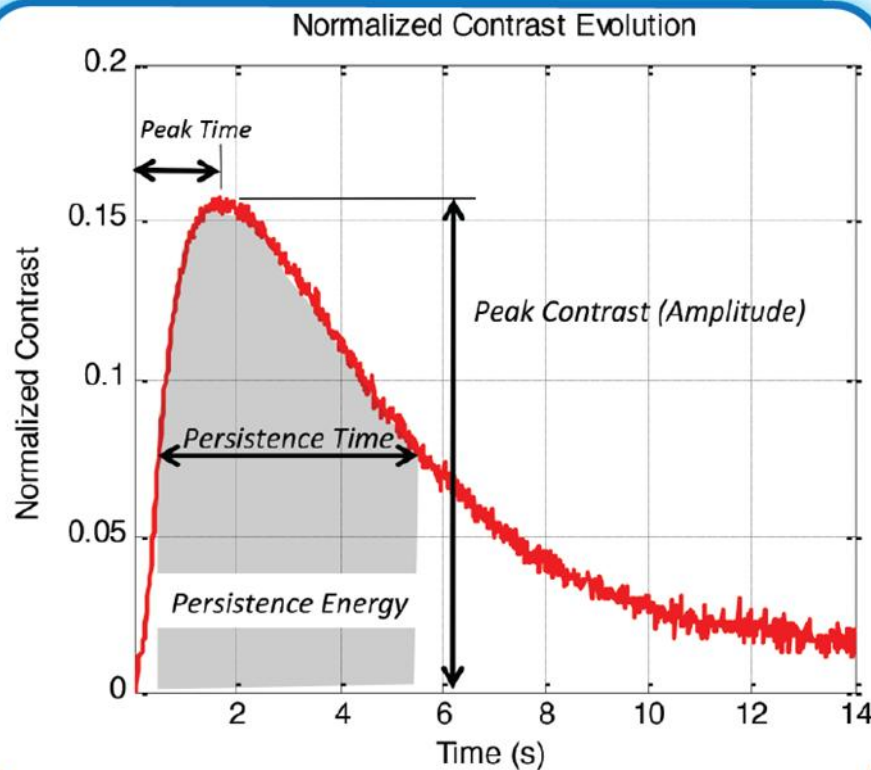
$$\Delta T_R = T_R - T_R^0$$

$$\overline{C}^t = \frac{\Delta T - \Delta T_R}{\Delta T + \Delta T_R}$$

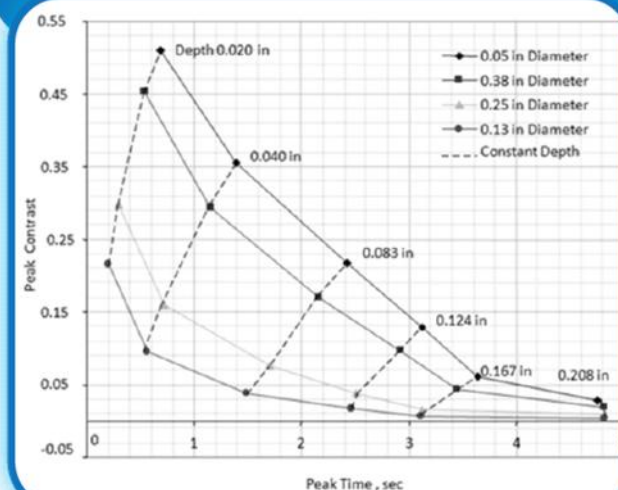
IR Contrast Measurements Relate to Flaw Detection, Measurement, and Monitoring



NORMALIZED CONTRAST EVOLUTION



PEAK CONTRAST AND PEAK TIME VERSUS VOIDS OF DIFFERENT DIAMETER AND DEPTH

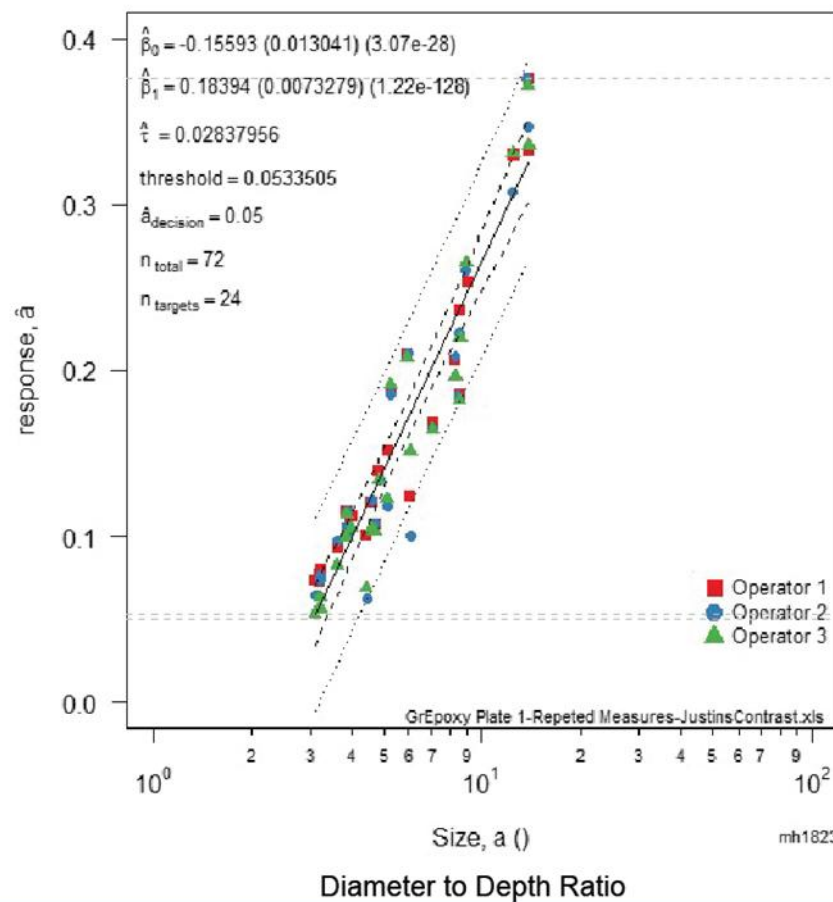


**SIMULATION RESULTS -
DEMONSTRATES BASIS FOR CALIBRATION**

Example of NDE MIL-HDBK-1823 Probability of Detection Analysis Based on Peak Contrast



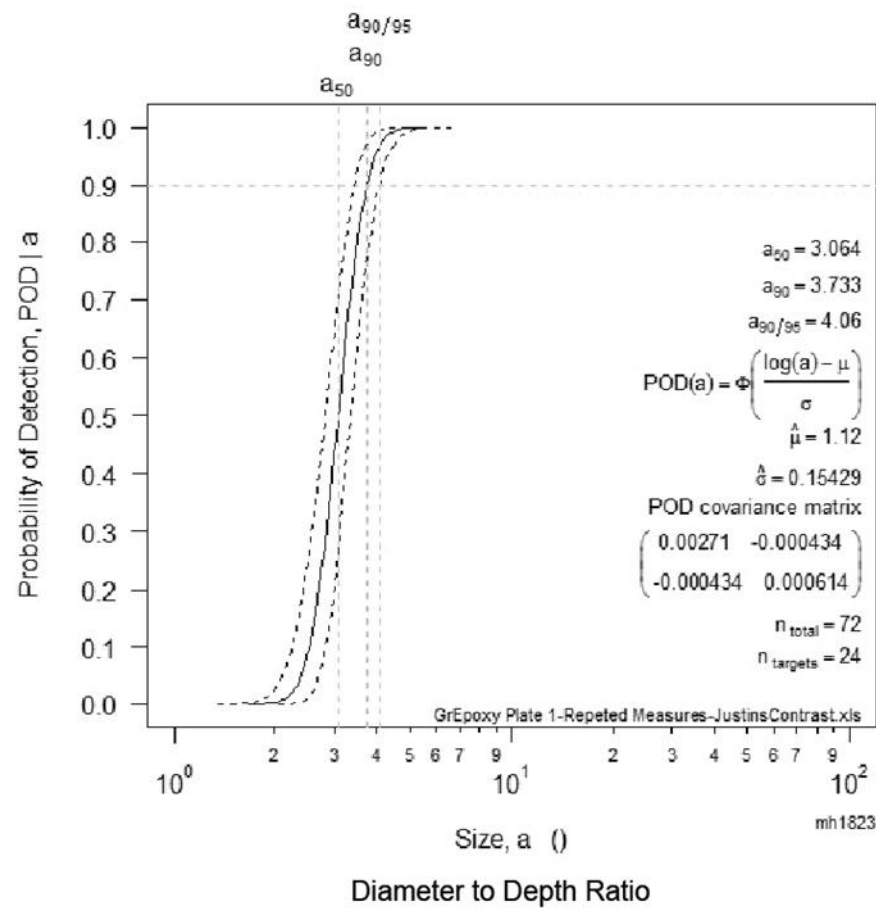
SIGNAL RESPONSE VERSUS
FLAW SIZE CORRELATION
(GENERALIZED LINEAR MODEL)



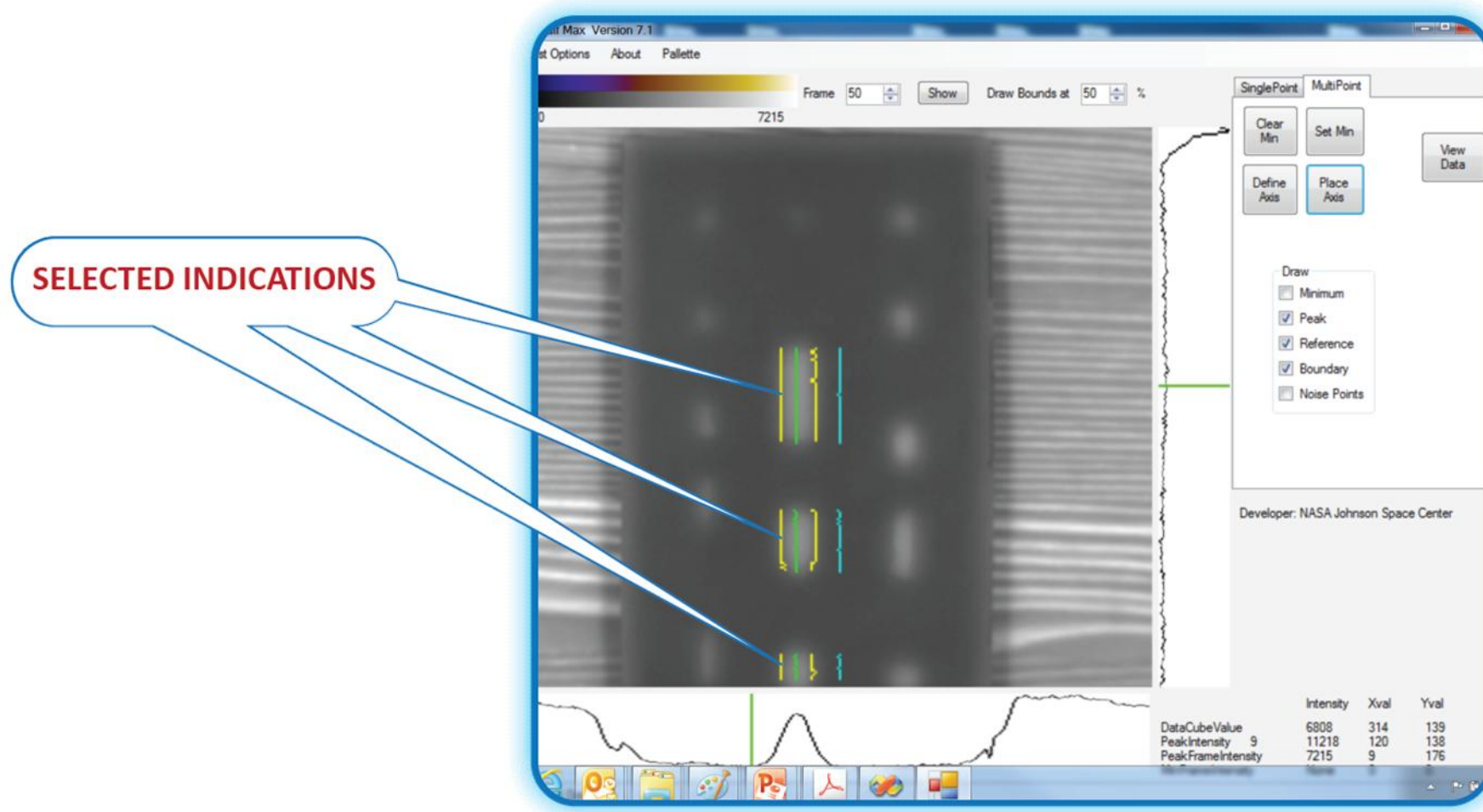
Example of NDE MIL-HDBK-1823 Probability of Detection Analysis Based on Peak Contrast



POD VERSUS FLAW SIZE

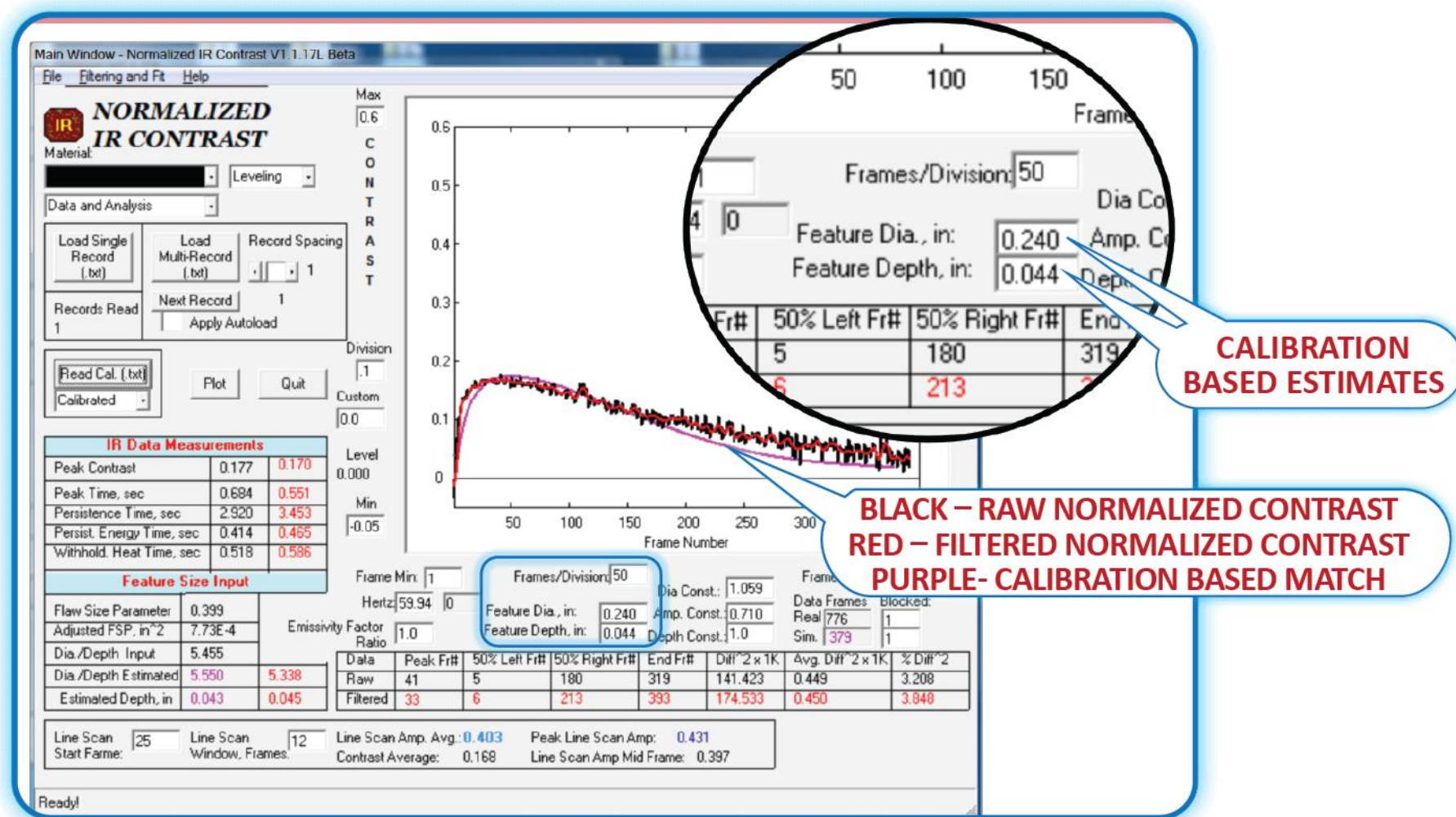


Multiple Point Contrast Data Extraction and Boundary Identification





IR Contrast Quantitative Analysis of Data



Quantitative Signal Amplitude Measures and Estimation of Flaw Size and Depth

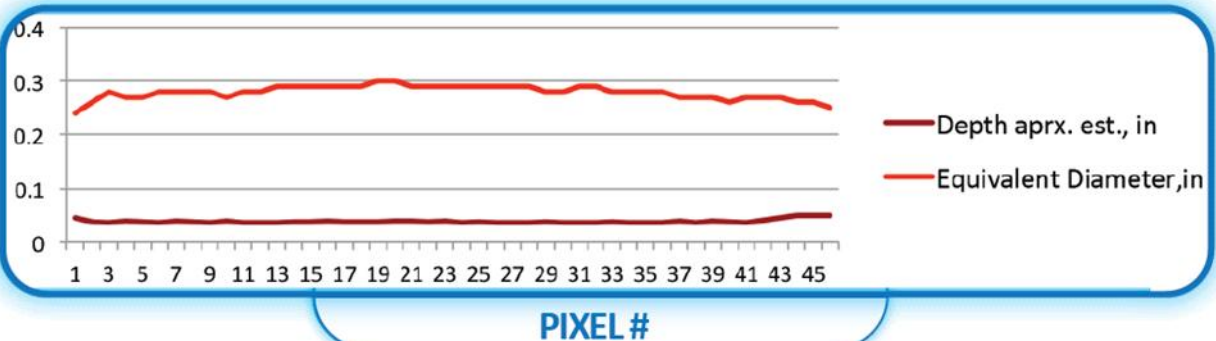
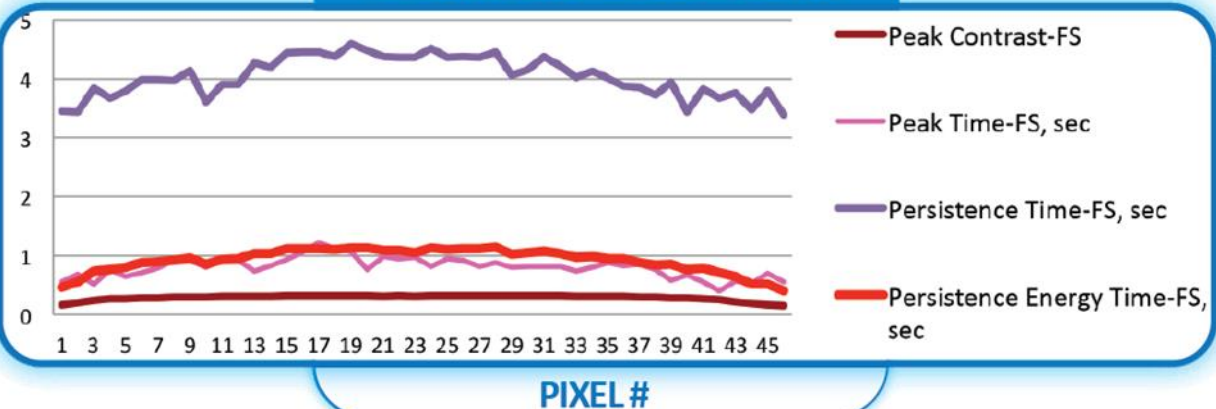


ANOMALY
ANALYZED



HALF MAX
DIAMETER OR WIDTH

IR CONTRAST CALCULATIONS



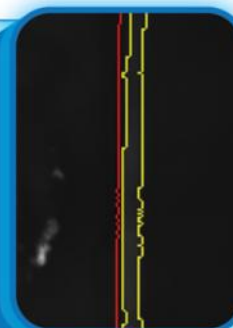
NDE of Space Shuttle Wing Flaw Size Mapping



FLASH INFRARED THERMOGRAPHY
INSPECTION OF
SPACE SHUTTLE WING LEADING EDGE

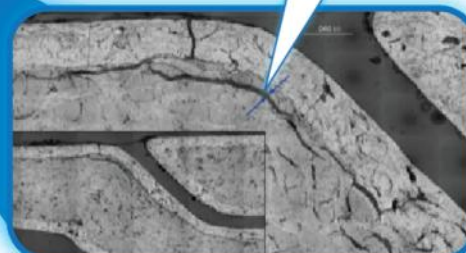


INFRARED THERMOGRAPHY IMAGE



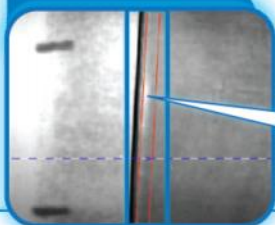
YELLOW LINES MARK
DAMAGE BOUNDARY

DELAMINATION



CROSS SECTIONAL IMAGE OF
TEST SPECIMEN

DELAMINATION
REGION

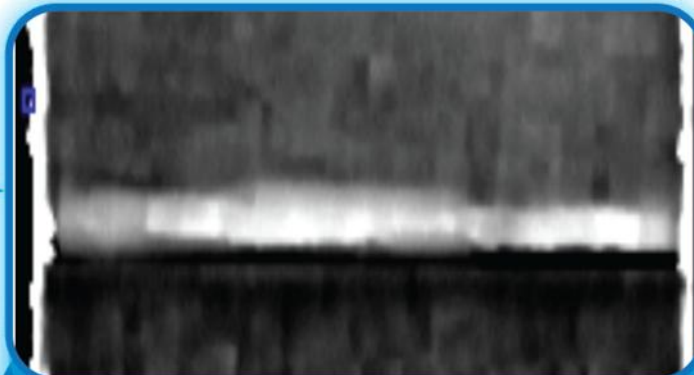


INFRARED THERMOGRAPHY IMAGE

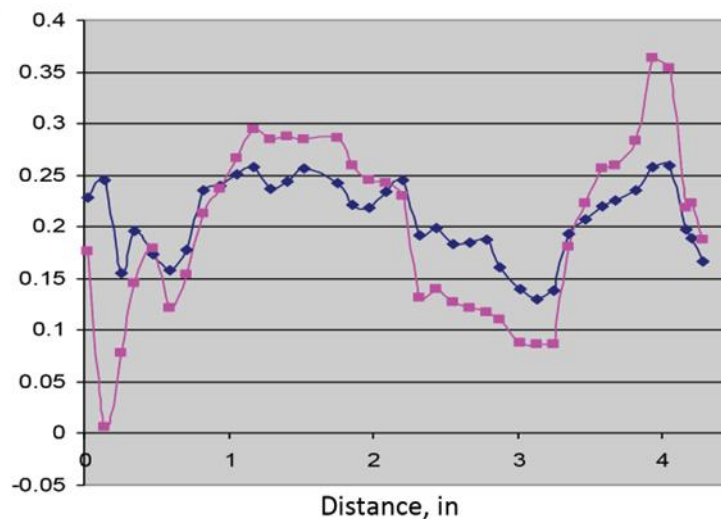
Quantitative Signal Amplitude Measurements: Persistence Energy and Peak Contrast



MEASUREMENTS ALONG
THE LENGTH OF ANOMALY

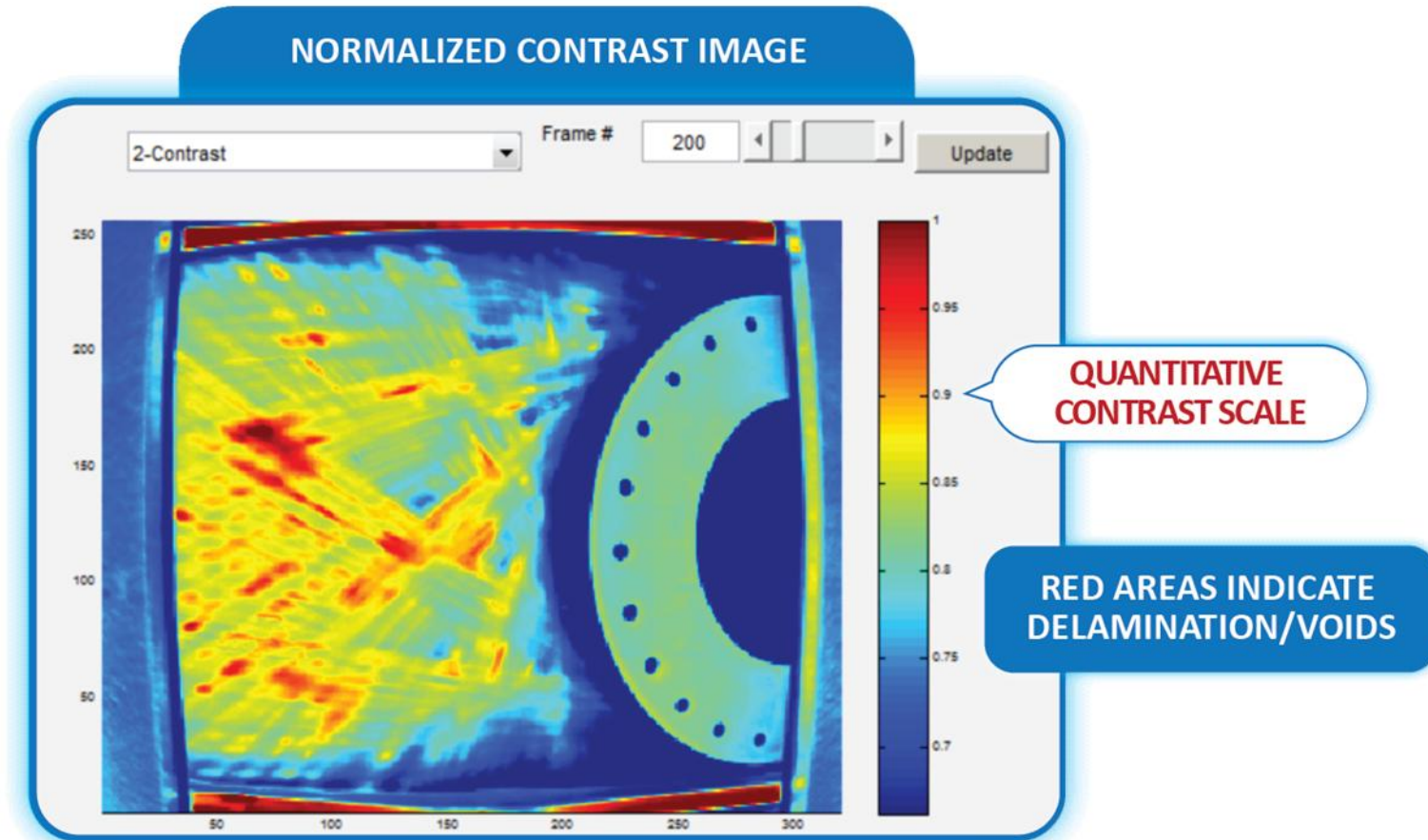


AMPLITUDE MEASUREMENTS
OF INFRARED THERMOGRAPHY
INDICATION



Peak Contrast
Persistence Energy, sec

Normalized Contrast Image Response to Flash Thermography

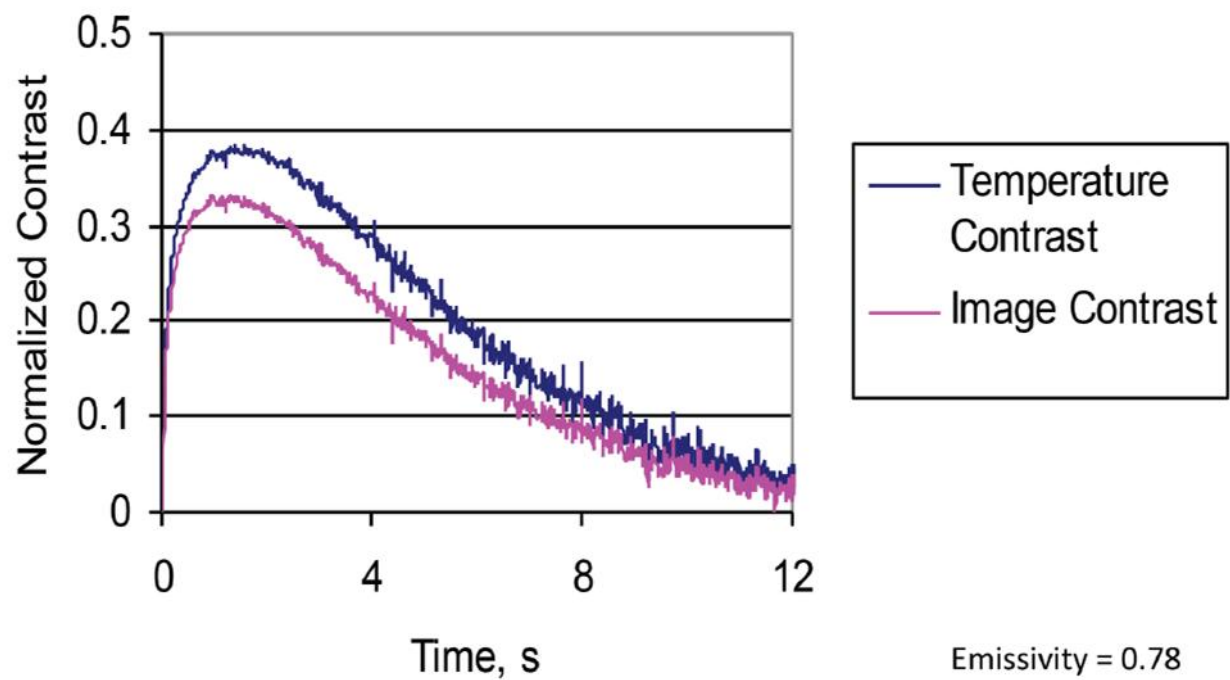


Quantitative scale is useful in threshold based
accept/reject decision of the inspection



Normalized Temperature Contrast

TEMPERATURE CONTRAST REDUCES EFFECT OF REFLECTIONS
PROVIDING HIGHER SIGNAL RESPONSE AND IMPROVING SENSITIVITY.



Advantages of IR Contrast Method



Provides characterization of flaws in nonmetallic composite materials and thin metallic materials

- Reflection correction and signal processing to improve signal to noise ratio improving flaw detection sensitivity
- Quantitative and qualitative information about shape/size, depth, and location
- Repetitive amplitude measurements suited for flaw growth monitoring
- Signal response similar to that in ultrasonic pulse echo testing
 - Helps NDE personnel in thermography inspection process, data analysis and interpretation
- Suitable for MIL-HDBK-1823 flaw size versus signal response Probability of Detection analysis
- Post processing can be adapted to existing infrared thermography data acquisition systems
- IR Contrast methods can augment current single sided IR data processing methods

Video Demonstration



Applications and Market





Applications

NDE OF NON-METALLIC STRUCTURAL COMPOSITES USED IN MANY INDUSTRIES...



AEROSPACE



POWER GENERATION



**CHEMICAL AND
PETROCHEMICAL**



MARINE



AUTOMOTIVE



CONSTRUCTION

Composites Market



Global Aerospace Composites Market
\$10.3 Billion In 2012



Demand for Composites is Expected to Grow
10 Percent *Per Year*

Strategic Opportunities and Partnership Development Technology Transfer and Commercialization Office



Your Entry Point For Partnering With JSC



Contact Us



● If you are interested in partnering or licensing, please contact ...

Michelle Lewis

E-mail: jsc-techtran@mail.nasa.gov

Phone: (281) 483-3809

● Connect with us online

<http://technology.jsc.nasa.gov>

Review Flash IR Thermography portfolio online

http://www.nasa.gov/centers/johnson/techtransfer/technology/MS-C-24444-1_Flash-IR.html#.U9ZwvPldWSo